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Experts, theories, and electric mobility: Toward an integrated conceptual framework for the adoption of electric vehicles

Abstract: I expand and integrate a theory of mobility (Automobility) with one of science and technology (Actor Network Theory) and one about social acceptance and user adoption (UTAUT). I apply this integrative framework to the diffusion (and non-diffusion) of electric vehicles and the process of electric mobility. I begin by presenting my methods, namely semi-structured qualitative research interviews with social theorists. Then, I present the three theories deemed most relevant by respondents. Automobility holds that, on a cultural or social level, automobiles exist as part of a complex, one that involves hardware and infrastructure—a hybridity between drivers and machines—along with patterns of identity and attitudes about driving pleasure. Actor Network Theory (ANT) involves the concepts of network assemblage, translation, enrollment, and actants and lieutenants. The Unified Theory of Acceptance and Use of Technology, or UTAUT, states that on an individual level, the adoption of new technologies will be predicated on interconnected factors such as performance expectancy, effort expectancy, and other facilitating conditions. Based largely on the original interview data supplemented with peer-reviewed studies, I propose a conceptual framework of user acceptance consisting of motile pleasure, sociality, sociotechnical commensurability, and habitual momentum. I conclude with implications for research and policy.

Keywords: Unified Theory of Acceptance and Use of Technology (UTAUT); Automobility; Actor Network Theory; electric vehicles

1. Introduction

The rise of the coveted automobile is sometimes depicted as one of the great achievements of the twentieth century. During the first half of the last century, the gasoline-powered vehicle evolved from a fragile, cantankerous, and faulty contraption to a streamlined, reliable, fast, luxurious, and widely affordable product (Moms 2004; Kirsch 2000). These automotive engineering feats were enhanced by the creation of interstate highway systems and urban infrastructure that have offered many people unprecedented mobility (Urry 2007).

However, the global proliferation of auto-dominated transportation systems and the monopoly of gasoline and diesel transportation fuels have germinated severe social and environmental consequences. These include costly traffic congestion and fatal accidents, deterioration of air quality, greenhouse gas emissions, and susceptibility to interruptions in supply and price volatility of oil (Brown and Sovacool 2011; Delucchi and McCubbin 2011; Woodcock et al. 2007). Yet transitioning away from our existing transportation system, Kemp et al. note (2012: p. xiv), may very well be "the hardest case" because "there are many stabilizing mechanisms and secular trends that point in the direction of more, not less, mobility." Moreover, in a meta-analysis about how people think about sustainability and environmental problems, Kormos and Gifford (2014) demonstrated considerable unexplained variance between self-reported, objective, and observed behavior. This could lead one to determine that we need better theoretical frameworks concerning transport and mobility to accommodate conflicting or at least confusing data.

To assist with this call for improved theoretical constructs, in this article I connect three theories to create a conceptual framework for electric mobility, a phenomenon brought about by electric vehicles (EVs) in all of their forms, from cars and buses to scooters and motorcycles. Electric mobility has the potential to improve the efficiency, affordability, and sustainability of transport (Mitchell et al. 2010; Train et al. 2012). By marrying advanced power electronics and computer controls with conventional and electric drivetrains, vehicles with battery electric motors typically operate more efficiently than those that run on internal combustion engines alone (Sovacool and Hirsh 2009). EVs could, in the extreme, potentially revolutionize our transport system for the better through a combination of improved technologies (Tran et al. 2013) and improved practices (Ryghaug and Toftaker 2014). Turton and Moura (2008) argue that EVs offer

a potential "paradigm shift" in how we conceive of future markets for energy and mobility. Mitchell et al. (2010) go even further to suggest that EVs are "transformative" as they change the "automotive DNA" underlying transport technologies, as Table 1 summarizes. While these claims are debatable (and partly challenged later on), they at least demonstrate that the topic of EVs and electric mobility is one deserving of more systematic, scholastic inquiry.

Table 1: Transformative Potential for the Electric Mobility Paradigm

Current paradigm	**Electric mobility paradigm**
Mechanically driven	Electrically driven
Powered by internal combustion engine	Powered by electric motors
Energized by petroleum	Energized by electricity (or hydrogen)
Mechanically controlled	Electronically controlled
Stand-alone operation	Potential for intelligent operation and interconnected management

Source: Modified from Mitchell et al. 2010

Based largely on original semi-structured research interviews coupled with an assessment of peer-reviewed studies, in this article, I ask: What do theories of mobility, science and technology, and user adoption tell us about the acceptance of EVs? More importantly, what are the benefits of theoretical unification should it be achieved? I begin by summarizing the key tenets of Automobility (from sociology and geography), Actor Network Theory (ANT) (from science and technology studies), and the Unified Theory of Acceptance and Use of Technology, or UTAUT (from management science and computing), as shown in Table 2. I then selectively draw from these theories to create an integrative framework of user acceptance centered on motile pleasure, sociality, sociomaterial commensurability, and habitual momentum.

Table 2: Overview of Theoretical Approaches to Electric Mobility

Theory/Concept	**Disciplines**	**Unit of analysis**	**Key concepts**	**Key authors**
Automobility	Sociology, political geography, mobility studies	Motion or the practice of mobility	Sociomaterial complexes, social identification and cultural symbolism,	John Urry, Tim Cresswell, Mimi Shellers, Jörg Beckman, Tim Dant, Michael Featherstone,

			driving pleasure, hybridity	Nigel Thrift, Peter Wells, Frank Geels, Rene Kemp, Geoff Dudley, Glenn Lyons
Actor Network Theory	Science & technology studies, sociology of scientific knowledge	Science and technology	Network assemblage, translation, enrollment, actants and lieutenants	Bruno Latour, Michel Callon, John Law, Steve Woolgar
Unified Theory of Acceptance and Use of Technology	Innovation studies, information systems, computing, management science	Individuals	Performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, experience and habit	Viswanath Venkatesh, Fred D. Davis, Susan A. Brown

To be fair, there are elements of each of these approaches that are incompatible. This is because at one level they have fundamentally different aims and assumptions. Automobility is an approach, or perhaps a concept that also has a critical, political agenda. ANT is concerned with ontology and epistemology, more focused on description and its understanding of how action comes about. The UTAUT is a theory that comes from inferential statistics. It operates with variables, operationalization and regression models and attempts to explain individual behavior. The penultimate section of the paper, however, shows that the three approaches work very well next to each other – each illuminates different aspects and complements isolated weaknesses.

In proceeding on this path, I aim to make three contributions. First and most specifically, I focus my framework around users, an often neglected dimension of large technical systems or sociotechnical systems (Oudshoorn and Pinch 2003; Schot et al. 2016). Much previous work has, for example, focused on "system builders" (entrepreneurial engineers who design and erect electricity networks or sewage systems, see Hughes 1983, Hughes 1987, and Melosi 2000 as examples) or taken infrastructure or technology as its unit of analysis, such as the "technological innovation systems" approach (Freeman 1987) or the "multi-level perspective" on technical

change (Geels 2002). By contrast, I look more deeply at how such broader factors interact with users. Indeed, I utilize the term "user" to refer to not only automobile owners, drivers, and passengers but others involved in the broader sociomateiral system including salespersons, traffic police, mechanics, and public officials. I thus attempt to go well beyond the traditional binary of narrowing users to "producers-consumers."

Second, and more pragmatically, a deeper understanding of the facilitators and impediments facing electric mobility has much relevance to current debates about alternative modes of transport. In this past decade, engineers and regulators have proposed a host of alternative fuels and modes—including natural gas powered cars, hydrogen fuel cells, and second generation biofuels—as necessary to move away from dependence on gasoline and oil in the transport sector (MacKay 2008; Geels et al. 2012). Comprehending the impediments and challenges faced by EVs illuminates how users may accept particular modes of mobility but reject others.

Third, based on interviews with 35 expert social scientists, I integrate aspects of three theoretical approaches—also phrased at times as "conceptual frameworks," "models," "theoretical constructs," "analytical frameworks," or "concepts"—seldom used together: Automobility, ANT, and the UTAUT. In their exhaustive review of the literature on public attitudes and transport behavior, Anable et al. (2006) suggest that approaches such as Schwartz's Norm Activation Model or Azjen's Theory of Planned Behavior, which focus on individuals, are used in isolation from broader ones analyzing communities, organizations, or the wider social and cultural environment. Previous research has, for instance, explored individual attributes to the adoption of new vehicles such as personal preferences for convenience (Gjoen and Hard 2002) or freedom (Sachs 1992). Axsen and Kurani (2012) investigate interpersonal influences such as a desire to inspire others or

symbolize environmentalism, whereas Stephenson et al. (2015) examine broader external forces such as fuel subsidies. Sheller (2012) approaches the topic through the angle of "master frames" of mobility and legitimacy. Rarely, however, are these insights combined. By synthesizing selectively but qualitatively from three theories, I seek to provide an integrated framework—centered on motile pleasure, sociality, commensurability, and momentum—that can explain electric mobility preferences across individual, interpersonal, socioenvironmental and network scales.

2. Research Method

My primary research tool for this study was semi-structured research interviews with knowledgeable experts ("theorists") about mobility and electric mobility. I interviewed 35 scholars over late 2015 and early 2016 reflecting 18 self-reported disciplines ranging from anthropology and behavioral science to science and technology studies and transport studies, as Appendix I indicates. These authors represented 26 separate institutions—mostly universities and a few research institutes—spread across seven countries: Canada (n=1), Denmark (n=1), Finland (n=1), the Netherlands (n=5), Norway (n=1), United Kingdom (n=13), and the United States (n=13). This pool of experts was admittedly a convenience sample, but the idea was to approach two different types of scholars: senior and eminent ones well known within theoretical debates, namely full professors or established researchers with highly cited articles (n=28); as well as junior researchers considered cutting edge and pushing concepts in the field (n=7).

In terms of the interview process, I asked only two open-ended questions: What theories or concepts are most useful at explaining the adoption of electric vehicles or mobility preferences? And, how can these be integrated, if at all? I asked a follow up question at the end of the interview for supporting articles, reports, books, and other sources of data for further information. To be

fair, these questions could also have been directed at non-electric forms of mobility or transport preferences in general—to be candid, they were directed only at EVs for two reasons. One, EVs are distinct from other transport options for having the transformative potential explained in the Introduction. Two, the nature of the grant funding the work (see the acknowledgments) dealt only with electric mobility and vehicle-to-grid integration, requiring a focus on EVs.

Interviews ranged from 20 minutes to four hours, with a mean time for most of 45 minutes. With permission, I present quotations from this material below with attribution. I recorded any theory or concept mentioned by participants; the three approaches mentioned more than 20% across all respondents—Automobility, ANT, and the UTAUT—are presented here and summarized by Table 3, and discussed in greater detail throughout the paper. Appendix II presents the full list of all 54 theories and concepts mentioned at least once by a respondent. Thus, there is an element of "grounded theory" in that only concepts, approaches, and theories "grounded" in the material are mentioned here. Put another way, my aim is not to cover all possible theories and concepts, of which there are probably hundreds, but instead to highlight those argued as most relevant or useful by the theorists interviewed.

Table 3: Most Frequently Mentioned Theoretical Approaches (Respondents=35)

No.	Name	Frequency mentioned by respondents (n)	Frequency mentioned (%)
1	Automobility	18	52%
2	Actor Network Theory	9	26%
3	The UTAUT	8	23%

Source: Author's compilation.

To present the data from this interview and selection process, I proceed to introduce Automoblity, ANT, and the UTAUT before discussing the virtues of theoretical integration. As I do this, a special note about terms and phrases. Various disciplines tend to use different language

to describe the process of where users embrace or reject EVs or electric mobility practices. The innovation and transitions literatures tend to emphasize "diffusion" or "adoption" whereas economists discuss "market acceptance" or "commercial acceptance" and transport planners emphasize "social acceptance" or even "use." Sociologists use terms such as "practice," "appropriation" or "domestication" whereas behavioral scientists may talk about "pro-environmental behavior" or "purchasing intentions" and still others frame the process as "sustainable innovation" or "choices." I employ the term "adoption" to encompass all of these things, and to refer to the process by which users own, drive, or otherwise use an EV.

3. Automobility

Automobility, a term initially coined by John C. Burnham (Flink 1975), comes from a broader "mobilities" agenda (Urry 2007; Sheller and Urry 2006; Hannam et al. 2006) investigating "the large-scale movements of people, objects, capital and information across the world, as well as the more local processes of daily transportation, movement through public space and the travel of material things within everyday life" (Urry 2000: 4). As Kirsch (2000: 6) summarizes, Automobility involves a "complex of cultural values, infrastructure networks, historic patterns of circulation and exchange, and technological artifacts."

At the core of this approach is the notion of "mobility." As Tim Schwanen (interview with author, 2016) put it:

> *Mobility is different from transport, as it is composed of a fragile entanglement of movement, representation, and practice. It is about more than discourse or language, and also includes sensory experiences such as noise, vibration, smell, and feelings of acceleration.*

Applied to private transport (encompassing EVs but also other modes and preferences), Automobility has come to encompass manifold technical, sociopolitical and cultural dimensions. It envisions the automobile as:

- A manufactured object produced by leading industrial firms;
- An item of individual consumption which provides its owners and users with sign-values such as speed, security, safety, and freedom;
- A powerful complex codified through broader interlinkages with financing firms, hotels, advertising campaigns and other social infrastructure;
- A hegemonic form of private mobility that subordinates other forms of transit such as walking or cycling;
- Part of a dominant car culture that sustains popular discourses about what constitutes a meaningful life or appropriate forms of modernity and citizenship;
- A culprit in environmental degradation and resource use resulting from the scale of material, space and power used over its lifecycle (Urry 2004).

Thus, Automobility de-centers and deemphasizes the importance of the single artifact—the vehicle—and replaces it with a more complex understanding of dynamic social and technical forces (Kirsch 2000).

Although Automobility is less structured and defined than some of the theoretical constructs in Appendix II, at least four of its themes emerged from the interviews for the purposes of this integrative study: sociomaterial complexes, social identification and symbolism, driving pleasure, and hybridity.

3.1 Sociomaterial complexes

Respondents noted that Automobility suggests that cars exist not in isolation but as part of a wider complex that involves material elements such as engines, tires, roads, and petrol stations all linked together as part of a system—making them it what respondents called "sociomaterial." As engineers perfected the conventional gasoline powered automobile, planners came to adopt various devices that were part of a high speed system of motorized transportation—grade separation of highway from city streets, traffic circles, divided dual highways, and synchronized stop lights. These changes to urban form created almost deterministic necessities of how cities should function, all rooted in auto-centric transportation (Sagoff 2008; Featherstone 2004). Wells and Xenias (2015) write that:

> *Automobility can equally be understood as the manifestation of embedded regimes in which core technologies are dialectically positioned in and around the purposive actions of vested interests. Car cultures thus come to be shaped by the technologies of the cars, by the road and support infrastructure, by legal frameworks and the degree of enforcement around such frameworks, and by issues such as climate and topography.*

Moreover, as John Urry (interview with author, 2016) states:

> *The notion that mobility involves a socio-material system gets us away from purely looking at technology or technique to focus instead on how automobility came to be assembled, the processes and continual sense of emergence that sustains it. There is of course still a materiality behind all of this, ranging from roads smooth enough to drive on to hotels, motels, cafes, and other elements of the system. It is necessary to have a systemic and intermodal perspective.*

What results is a complex or regime of Automobility where private cars operate in combination with, and continually reproduce, a series of components and mutually aligned infrastructural elements (Kemp et al. 2012).

A key part of the Automobility approach is stepping back to evaluate more than just a single car or the practice of driving, and to assess normatively the entire socio-material complex

needed to facilitate the manufacturing and use of automobiles. As Rene Kemp (interview with author, 2016) notes:

> *There is an element of normativity when assessing whether particular modes of transport, such as EVs, are "good" or "bad" for society. One must look at system wide effects. Whether EVs are sustainable or not depends on how they interact with other modalities.*

For instance, as Table 4 summarizes, there may be situations, practices, or socio-material configurations where EVs meet principles of justice, sustainability, or sustainable development, but also areas where they may not (such as when an EV merely represents an additional car, and thus becomes a net environmental burden, or increases the demand for motorized mobility at the expense of more active walking and cycling). This challenges the rather simplified and overly optimistic studies mentioned above in the Introduction about the value to EVs and electric mobility, underscoring a relational or contextual dimension to mobility. As Peter Wells (interview with author, 2016) adds:

> *Sustainable automobility is about the total package, the materials a car is designed from, its power train, how it's produced, how it is driven, how revenues are derived from the vehicle in use rather than selling the car and moving on. This touches upon supply chains, manufacturing, use and behavior, and end use as well as capturing value from new markets and ways of thinking.*

Automobility's emphasis on complexes also reminds us that practices of mobility can have a hard hegemonic or imperialist edge. Sheller (2014: 251-252) reveals how demand for materials needed in the car such as aluminum are tied intimately to the discursive coproduction of other regions of the world as backwards, slow, and relatively immobile.

Table 4: Socio-Material System-Effects of Electric Mobility

Interacting developments	**Dimension**	**Positive impacts**	**Negative impacts**

Transport-related	Intermodality	Use of EV within systems of intermodality, in combination with measures to discourage car use	Use of EV in systems that encourage excessive driving and EVs as second or third (luxury) cars
	Desire for motorized transport	Substitution of cars and scooters	Increase in car-based mobility
	Organized car sharing	Use of EVs in car sharing/ride sharing schemes	Increase in preferences for private, single-occupancy driving practices
	Increases in mobility	Implemented in tandem with active transport planning (walking, cycling)	Extra car trips, multiple car ownership, displaces enthusiasm for cycling
Non-transport related	Zero-carbon & low carbon electricity	Use of EV in countries with de-carbonized electricity grids	Use of EV in countries with coal-based electricity
	Smart grids	Charging at off-peak times and storage for peak demand	Charging at peak times with no storage
	Critical materials scarcity	Efficient manufacturing techniques with an appreciation for externalities with battery recycling	Inefficient and polluting manufacturing techniques with no battery recycling
	Employment, competitiveness, and growth	Designed and promoted by sustainable firms with a focus on innovation and entrepreneurship	Coopted and marginalized by transnational conglomerates with little desire for social change

Source: Modified from Kemp (interview with author, 2016).

3.2 Identity and symbolism

Automobility highlights non-material aspects of cars and driving as well, and it attempts to explain how cars become connected to particular symbols of status. As Linda Steg (interview with author, 2016) explains:

> *Much of mobility behavior is not based on reasoned action. Many times emotional factors play a role. Moreover, many studies focus on instrumental factors that explain travel behavior, such as travel costs, or travel times. However, symbolic and affective aspects appear to play a key role.*

Given the extension of cars into social, cognitive, and cultural realms, Automobility holds that the act of driving is a profoundly social process—one that both shapes and is shaped by norms, attitudes, and practices. These include the services that automobiles provide drivers, such as desire for solitude, personal security, speed, freedom, and even sexual desire. It also encompasses the interlinkages that automobiles have with other aspects of social or cultural life, such as commuting to work, eating food, or taking a vacation (Cohen 2006). Automobiles can lastly become an important status signal, signifying or symbolizing wealth or masculinity (Walker et al. 2000).

3.3 Driving pleasure

Because drivers invest emotionally as well as economically in their cars, the literature on Automobility supposes that cars create affective contexts that culminate in "the joy of driving." This "joy" can be encapsulated in the notion of "driving pleasure," often defined as a mix of engine power, speed, and drivability (Ryghaug and Toftaker 2014). To be sure, this "joy" need not always be based in utilitarian calculations; in some instances it can be an amalgamation of aesthetics, sensory responses, and notions of social or environmental sustainability (Sheller 2004). As Wells and Xenias (2015) compellingly argue:

> *For many individuals the car has come to be defined as an extension and public expression of the self, and as such tends to generate powerful emotive content such that it is attributed with the ability to convey and confer social meaning*.

It is often difficult to parse the value of driving itself from other activities connected to it such as the purpose of a journey, traveling companions, or degree of traffic congestion (Handy et al. 2004). User-defined pleasure is thus also linked, in part, to extrinsic, external or contextual aspects such as road quality, travel expediency, or safety (Hagman 2010).

3.4 Hybridity

A final important theme from Automobility is that of hybridity: the car-driver as a "hybrid" or "cyborg" combination of specific human actions, machines, and supportive social infrastructure (Urry 2004). This car-driver hybrid or "motile hybrid" is more than simply a person or an object—it is "neither objects, nor subjects; neither at rest, nor on the move – they are embodied ambiguity" (Beckmann 2004). In other words, human beings are transformed the moment they enter an automobile and start moving, and the automobile is transformed as well when it is driven. Subject and object come together in motion in ways unique to Automobility. As Dant (2004) notes, "The driver-car is neither a thing nor a person; it is an assembled social being that takes on properties of both and cannot exist without both." This framing of hybridity captures that the car is an extension of the human body into a new technological domain, and also that the machine itself becomes humanized through the social act of driving.

4. Actor Network Theory

The second preferred approach, Actor Network Theory (ANT), seeks to offer an explanation for how scientific or technical objects (usually called "artifacts") become integrated into society (Latour and Woolgar 1979; Callon 1986; Callon and Latour 1986; Law 1999). ANT suggests that artifacts are not things in the usual sense, but what Feenberg (2001: p. 114) calls "nodes in a network that contains both people and devices in interlocking roles." ANT proposes that the social alliances in which technology are constructed are bound together by the very artifacts they create. ANT, then, attempts to uncover the facts, machines, people, and bureaucracies that must be aligned, molded, and disciplined to create technological development and acceptance; these combine to make up the actor world, an "overall environment that provides the conditions for a technology to succeed" (Mort 2001: 17). ANT reveals that the diffusion or

adoption of technology is a fervently spatial process involving "societal embedding" across multiple scales (Geels and Johnson 2016) and it also proposes that "there are no actors without networks" by emphasizing "bricolage, heterogeneity and messiness of technological development in local practices" (Grin et al. 2010).

Admittedly, the approach is vast—some call it a theory, others an "approach" or even a "material-semiotic method" (Latour 2005). Law (2009: 4-5) suggests that it ANT "is a disparate family of material-semiotic tools, sensibilities, and methods of analysis that treat everything in the social and natural worlds as a continuously generated effect of the webs of relations within which they are located." Nonetheless, respondents suggested that four of its themes are useful in the context of mobility: network assemblage, translation, enrollment, and actants and lieutenants.

4.1 Network assemblage

Although it finds its roots in both ANT and French social theory (Deleuze and Guattari 1972, 1987), a network assemblage has come to refer to the ordering of dissimilar entities so that they work together towards a common goal for a particular period of time. As Deleuze and Parnet (1987: p. 69) articulate, assemblage entails:

> *A multiplicity which is made up of many heterogeneous terms and which establishes liaisons, relations between them across ages, sexes and reigns – different natures. Thus, the assemblage's only unity is that of co-functioning: it is a symbiosis, a 'sympathy.'*

Network assemblages are always relational, arranging human and technical components to form a new unified whole; they are complex, being socio-material or crossing the nature-culture divide; and they are dynamic, constantly coupling continuous flows and objects that are otherwise fragmentary (Müller 2015). In the absence of one key network component, the entire assemblage breaks down.

Like Automoblity, network assemblages can be noteworthy, then, for decentering the technological artifact as the object of inquiry and expanding scholastic focus on "technology" to include the vast social and cultural networks surrounding it. According to Latour (1987: p. 160), scientists and engineers:

> *travel inside narrow and fragile networks, resembling the galleries termites build to link their nests to their feeding sites. Inside these networks, they make traces of all sorts circulate better by increasing their mobility, their speed, their reliability, their ability to combine with one another.*

And, as John Urry (interview with author, 2016) adds:

> *The adoption of automobiles is the product of a complex power play between divergent actors and their interests.*

By focusing on the relational and political aspects between engineers, inventors, analysts, politicians, artifacts, manufacturing techniques, marketing strategies, historical context, economics, and social and cultural factors, an assemblage highlights that technology emerges through a seamless web of material objects and immaterial epistemologies.

4.2 Translation

As network assemblages gain credibility or solidify, they move through what Callon (1986) has termed the process of translation. Indeed, this is why Latour (2005) even calls ANT a "sociology of translation." Translation begins with problematization, framing an assemblage as a vital way of addressing some pressing problem or fulfilling a social need. Actors, in other words, see a technology as consistent with their own agendas, and the process of problematization establishes a particular assemblage as an "obligatory passage point" that renders the system or technology "indispensable" to their interests. Translation becomes not only a definition of roles but the delineation of a particular storyline and scenario to fulfill.

Mahring et al. (2004) add that problematization also involves creating roles and identities for each actor in the network to help inscribe or humanize the technology with a degree of stability and relevance to both individuals and organizations, fitting very much in line with Automobility's notion of hybridity. As Callon (1985: 24) explains:

> *An actor-world associates heterogeneous entities. It defines their identity, the roles they should play, the nature of the bonds that unite them, their respective sizes and the history in which they participate*.

4.3 Enrollment

Once novel networks begin to mature, they begin the later stages of translation: interesessment, enrollment, and mobilization, categorized here under the term enrollment because Callon (1985; p. xvi) uses it to broadly encompass "methods by which an actor enrolls others." Interesessment refers to the strengthening of the network between actors and other support structures. It attempts to emphasize network effects, that entities or actors have no inherent qualities, attributes or agency on their own, but take their form as a result of relationships only in comparison with other entities (Wong 2016). Then comes the wider enrollment and mobilization of allies. In creating the assemblage, a diversity of animate and concealed entities must be enrolled into the network so that their primary function becomes the promotion of that network. Thus, network assemblages are sutured not through objective knowledge practices but a subtle process of indoctrination and enlistment of resources (Latour 1987; Callon 1986). Actors become translated or socialized into the network and then enroll others to do the same.

4.4 Actants and lieutenants

Actants and lieutenants are terms used to denote the nonhuman dimensions to network assemblages. Even a simple technology like a door opener (or in another infamous paper, sea scallops) remains connected to a larger network of concepts (pull and push) and physical artifacts

(walls and doors). The door opener acts as a "lieutenant," and Latour and Johnson (1988: 310) posit that:

> *In our societies, there are thousands of such lieutenants to which we have delegated competences, it means that what defines our social relations is, for the most part, prescribed back to us by nonhumans. Knowledge, morality, craft, force, sociability are not properties of humans but of humans accompanied by their retinue of delegated characters. Since each of these delegates ties together part of our social world, it means that studying social relations without the nonhumans is impossible.*

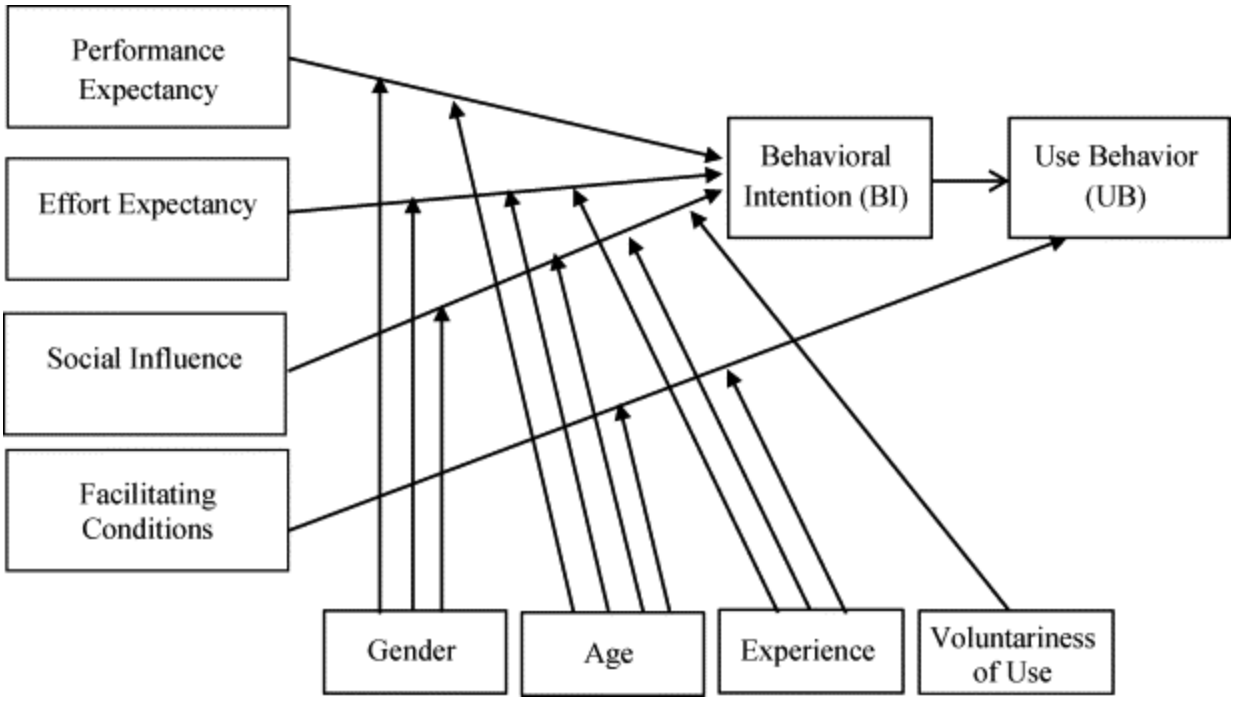
This later becomes termed an "actant," any type of component—biological, technical or otherwise—that can exert influence over the network (Risan 1997). Actants have agency and can serve as intermediates promoting the growth of, or constraining, the network. They represent what ANT theorists sometimes call "the missing masses" of non-human influence.

5. Unified Theory of Acceptance and Use of Technology

The third preferred approach, the Unified Theory of Acceptance and Use of Technology, hereafter UTAUT, was introduced to explain the adoption of new technologies by combining eight different theories summarized in Appendix III. These include Azjen's Theory of Planned Behavior, Davis' Technology Acceptance Model, and Roger's Innovation Diffusion Theory, among others. In its initial form, the UTAUT hypothesized that four key elements—performance expectancy, effort expectancy, social influence, and facilitating conditions—determined whether a user would adopt a new technology at the workplace (Venkatesh et al. 2003).

The UTAUT proposes that perceived usefulness (performance expectancy), perceived ease of use (effort expectancy) and social influence (norms) affect technology use via behavioral intention, whereas facilitating conditions directly antecede behavior. In addition, individual difference variables such as age, gender, experience, and voluntariness moderate the relationship between the four key elements, leading to a typology of acceptance shown in Figure 1.

Figure 1: The Original Unified Theory of Acceptance and Use of Technology (UTAUT)



Source: Modified from Venkatesh et al. 2003.

Applied to the domain of office computers and information systems, its originators argued that the UTAUT explained about 70 percent of the variance in behavioral intention to use technology and about 50 percent of the variance in that technology once it is utilized (Brown and Venkatesh 2005). Since then, the theory has been augmented to apply beyond the workplace with an additional three core elements: hedonic motivation (a key predictor from consumer behavior research), price value (a key predictor from economics), and habit (a key predictor from sociology) (Venkatesh et al. 2012). Its theorists also removed voluntariness of use as a moderating factor.

In its original and extended forms, the UTAUT has had a significant influence on academic scholarship examining information systems and computer software (Marchewka et al. 2007), mobile telephony and smart applications (Gurtner et al. 2014; Park et al. 2007), collaborative technology and networks (Lin et al. 2008), health information and healthcare (Kijsanayotin et al. 2009; Holden et al. 2010), education and learning (Chiu et al. 2008), internet practices and online banking (Martins et al. 2014; Zhou et al. 2010), and even tourism (Martin et al. 2012; Escobar-

Rodríguez et al. 2014). Systematic reviews and meta-analyses have also tended to affirm the theory's explanatory power (Lee et al. 2003; Legris et al. 2003; King et al. 2006; Bagozzi 2007). As one meta-analysis noted, "[the UTAUT] is believed to be more robust than other technology acceptance models in evaluating and predicting technology acceptance" (Taiwo and Downe: 2013). Indeed, one content analysis in 2011 stated that the UTAUT had already been used and cited more than 11,000 times (Williams et al. 2011).

In its most recent incarnations, the UTAUT posits that users will base their decision to adopt a new technology on the seven salient dimensions. These conditions remind us first and foremost that automobiles are designed for particular intended uses. As Tim Schwanen (interview with author, 2016) put it:

> *Nothing is coincidental when it comes to the environment of the automobile. Its ergonomic design has been carefully tailored for user experience and sensory input. Everything from the way it looks and drives to how it smells and the way the door clicks has been designed. The car is probably the single most engineered space routinely occupied by some members of humanity.*

5.1 Performance Expectancy

Performance expectancy was initially defined as "the degree to which the user expects that using the system will help him or her attain gains in job performance" (Venkatesh et al. 2003: 447) and later extended to include performance outside of the office (Venkatesh et al. 2012). This construct finds its roots in perceived usefulness from the Theory of Planned Behavior, extrinsic motivation from the Motivational Model, and outcome expectations from Social Cognitive Theory. More broadly, performance expectancy has come to mean the degree to which a technology will provide benefits to users in performing particular tasks. The construct is tied strongly to utility, which Veknatesh et al. (2003) suppose is one of the "strongest predictor[s] of behavioral intention."

5.2 Effort Expectancy

Effort expectancy is "the degree of ease associated with consumers' use of technology" (Venkatesh et al. 2003: 449). This construct finds its roots in concepts such as perceived ease of use from the Technology Acceptance Model, complexity from the Theory of Human Behavior, and ease of use from Innovation Diffusion Theory. Oh et al. (2009) further decompose effort expectancy into the simplicity or complexity of the technology in question, its actual ease of use, and its perceived ease of use.

5.3 Social Influence

Social influence refers to "the degree to which an individual perceives that important others [e.g., family and friends] believe that he or she should use the new system" (Venkatesh et al. 2003: 451). It finds its roots in concepts such as subjective norms from the Theory of Reasoned Action and the Theory of Planned Behavior, social factors from the Theory of Human Behavior, and image in Innovation Diffusion Theory. Lucas and Spitler (1999: 304) argue that "organizational variables such as social norms and the nature of the job are more important in predicting the use of technology than are users' perceptions of the technology." In a meta-analysis, Schepers & Wetzels (2007) also found that social norms were vital in influencing users' attitudes.

5.4 Facilitating Conditions

Facilitating conditions are defined as "the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system" (Venkatesh et al. 2003: 453). They relate to the perceptions that users have of the technical or organizational infrastructure in place or support available to perform a task or adopt a new system. This construct embodies perceived behavioral control from the Theory of Planned Behavior, facilitating conditions from the Theory of Human Behavior, and compatibility from Innovation Diffusion

Theory. Venkatesh et al. (2008) in later work emphasize that such conditions can play a strong influence in the duration, frequency, and intensity of use in new office information systems.

5.5 Hedonic Motivation

Hedonic motivation—later added to a modified version of the UTAUT—is defined as "the fun or pleasure derived from using a technology" (Venkatesh et al. 2012: 161). It is meant to encompass the perceived or popular enjoyment that using a new technology provides. Work in consumer studies has confirmed that hedonic factors exert strong influence over the determinants of technology adoption and use (Childers et al. 2001), and some anthropologists have gone so far as to label humans "hedonic calculators" (Douglas and Wildavsky 1983).

5.6 Price Value

Price value—also added later—is defined as "consumers' cognitive tradeoff between the perceived benefits of the applications and the monetary cost for using them" (Venkatesh et al. 2012). A meaningful difference between consumer and organizational settings is that in private consumption, users bear the monetary cost of new systems. In marketing research, the monetary cost or price is usually conceptualized together with the quality of products or services to determine their perceived value, which can have a negative or positive impact on purchasing intention (Zeithaml 1988; Dodds et al. 1991).

5.7 Experience and Habit

Experience and habit—added later—is the final construct utilized in the UTAUT. Experience is defined as "passage of time from the initial use of a technology by an individual" and habit is defined as "the extent to which people tend to perform behaviors automatically because of learning" (Venkatesh et al. 2012). Research in management science notes that experience and habit as prior use can be powerful predictors of continued use (Limayem et al. 2007; Kim and

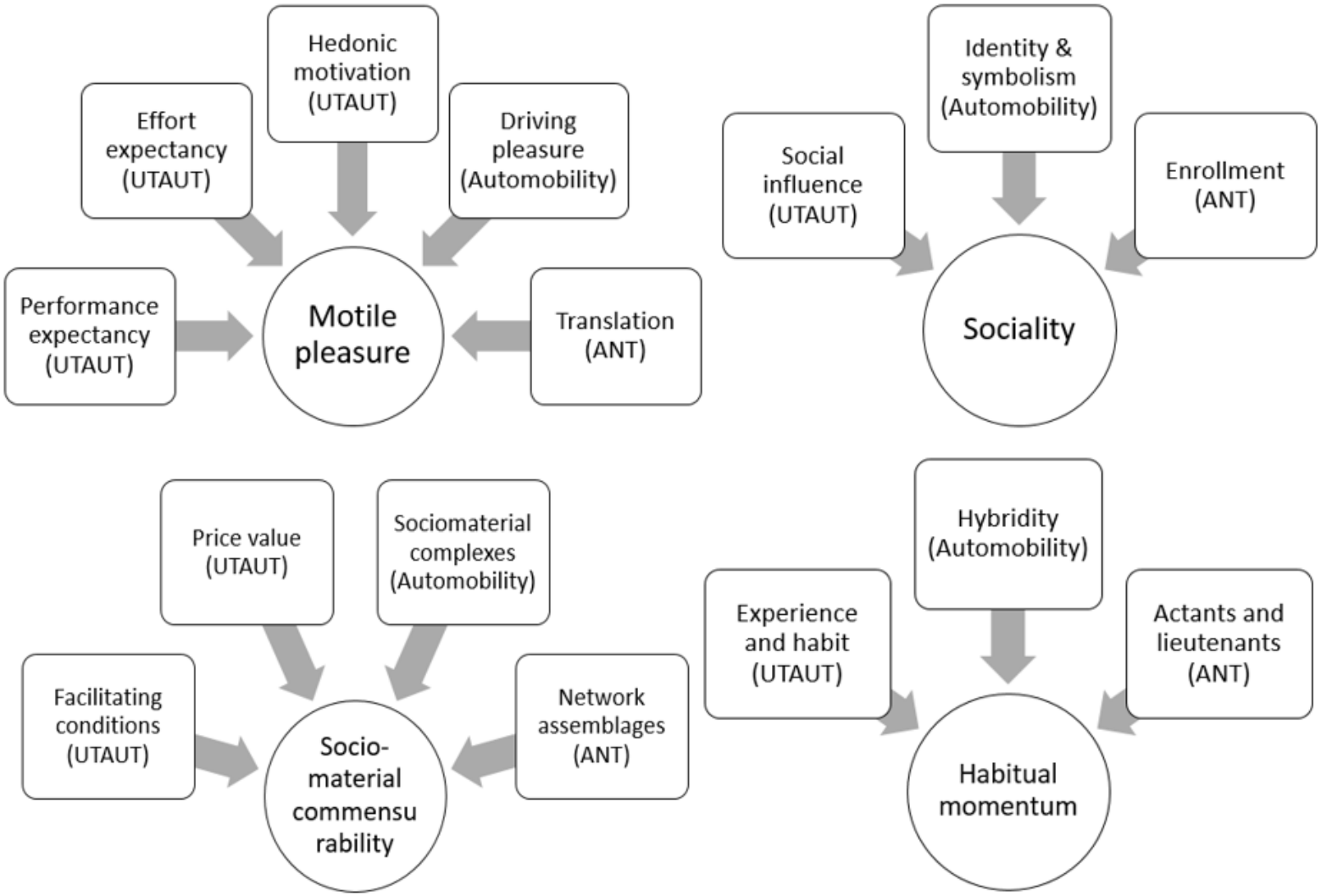
Malhotra 2005); other research in psychology indicates that feedback from previous experiences will influence beliefs and thus future behavioral preference (Azjen and Fishbein 2005).

6. Towards an Integrated Framework for Electric Mobility

Although they originate in different disciplines and have their own conceptual typologies, terminologies, and assumptions, the three theories—one of mobility, one of science and technology, and one of acceptance—possess remarkably similar attributes. This section of the paper attempts to selectively synthesize parts of them. In doing so, it sets to achieve calls for a more unified, cross-disciplinary framework (a sort of "meta-theoretical principal components analysis") that can assess electric mobility driving practices across types of actors as well as geographic scales.

To offer greater theoretical synergy, this part of the manuscript argues that the adoption of EVs will generally depend on four integrated concepts: motile pleasure, sociality, sociotechnical commensurability, and habitual momentum. Figure 2 illustrates how the four concepts unify the fifteen elements from Automobility, ANT, and the UTAUT discussed above. Each of these synthesized concepts is introduced in turn before empirical support is offered from the peer-reviewed literature. The section of the paper to come shows how such integration avoids some of the pitfalls of depending on each theory in isolation.

Figure 2: An Integrated Conceptual Framework for Electric Mobility



Source: Author. Note: UTAUT= The Unified Theory of Acceptance and Use of Technology. ANT=Actor Network Theory

6.1 Motile pleasure

Motile pleasure incorporates three elements from the UTAUT—performance expectancy, effort expectancy, and hedonic motivation—with Automobility's notion of driving pleasure and problematization from ANT. Motile pleasure can therefore refer to the joy of driving a vehicle rooted in utilitarian calculations, such as fuel efficiency and cost savings, or speed of travel, or in addressing other non-economic concerns ("problems") such as family safety or environmental sustainability. It can arise out of a vehicle performing well, out of it requiring minimal effort on the part of the operator, or out of other motivations satisfying a social need or affecting an emotional response.

For instance, multiple studies confirm the presence and salience of utilitarian or hedonic attributes as applied to various forms of electric mobility. Many authors suggest that EVs have perceived economic or utilitarian benefits such as cheaper "fuel" expenses compared to gasoline prices (Zhou et al. 2015; Kihm and Trommer 2014; International Energy Agency 2013; Green et al. 2011) or the fact that when connected to the grid EVs can become sources of income which provide energy storage or grid services (Sovacool and Hirsh 2009; Galus et al 2010; Wolsink 2012). Axsen et al. (2013) comment that EVs can engender pleasure (or displeasure) across societal-functional dimensions based on the cleanliness of electricity fueling them; private-functional dimensions such as battery life; and private-symbolic dimensions such as sportiness. Some studies note the heightened performance of EVs compared to their counterparts in terms of not only efficiency but acceleration or "smoothness" and "quietness" of ride (Ryghaug and Toftaker 2014; Tran et al. 2013; Tran et al. 2012; Daziano and Chiew 2012). Others have affirmed that EVs require minimal maintenance and generally less effort to own or operate (Mwasilu et al. 2014; Neubauer et al. 2012).

6.2 Sociality

Sociality blends together social influence from the UTAUT, social identification and cultural symbolism from Automobility, and enrollment from ANT. Sociality suggests that subjective norms and judgments from those a driver trusts—family, friends, peers, intermediaries—will influence adoption behavior along with the ability for a vehicle to enhance a driver's identity or sense of freedom, individuality, power, and so on. Automotive and fuel companies sometimes even make the association between driving and independence or freedom explicit in their advertising. People therefore become enrolled or socialized into identifying themselves as EV adopters or drivers seeking to satisfy desires. As Donald MacKenzie (interview with author, 2016), adds:

> *When someone buys a car, it says something about them and how they see the future. These symbolic elements are packaged into the purchase decision.*

Marianne Rygaug (interview with author, 2016) lends further support to this argument that EV purchasing and use is a social phenomenon when she notes that:

> *People must be recruited into the adoption of an electric vehicle.*

Linda Steg (interview with author) clarifies that:

> *People are more likely to adopt an electric vehicle when they believe doing so will enhance their status and demonstrate who they are. Also, people feel good when they engage in pro environmental actions because doing so is meaningful; anticipating such positive feelings encourages pro-environmental actions. This good feeling may literally manifest itself as a warm glow, an implicit association. Much of this process is not conscious.*

Previous research has confirmed that automobile preferences in particular relate to a constellation of norms, interpersonal judgments, or affirmation of identity. First are those studies discussing the importance of factors such as "interpersonal influence" and social networks as they relate to EV acceptance (Axsen et al. 2013; Axsen and Kurani 2011; Axsen and Kurani 2012; Axsen and Kurani 2013; McCoy and Lyons 2014). Another strand of research finds that that EV adoption affirms lifestyle identities related to sustainability or innovativeness, such as being "green" or labelled an "early adopter" (Kahn 2007; Graham-Rowe et al. 2012; Schuitema et al. 2013; Sovacool and Blyth 2015), or even notions of security and "cocooning" found in larger vehicles (electric and non-electric), enabling cars to insulate occupants from otherwise noisy or unpleasant aspects of daily life (Wells and Xenias 2015). Lastly come those studies concluding that broader images or symbolism related to confidence in industrial competitiveness, nationalism, security, responsibility or environmentalism affect electric mobility preferences (Axsen and Kurani 2003; Graham-Rowe et al. 2012; Melton et al. 2016).

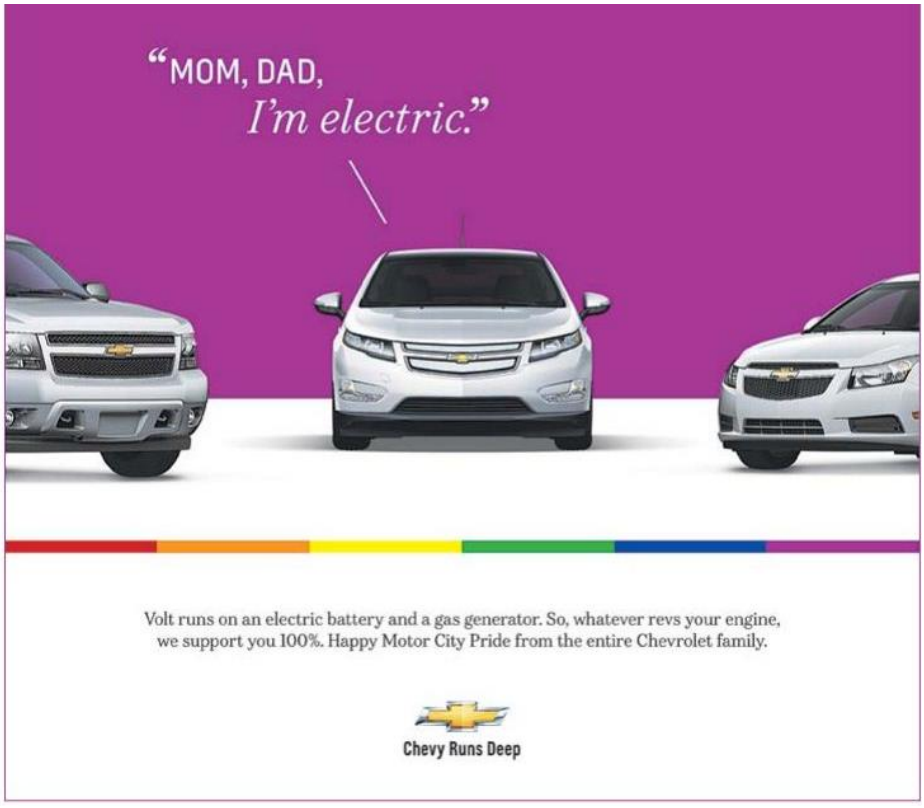
6.3 Sociomaterial commensurability

Commensurability refers to the degree of compatibility with existing material infrastructure as well as the particular lifestyle of users. Commensurability incorporates facilitating conditions and price value from the UTAUT, sociomaterial complexes from Automobility, and network assemblage from ANT. Facilitating conditions touch upon infrastructural elements such as charging stations or availability of reliable electricity whereas price value touches upon who pays for them (public or private charging, free or tariff based). Sociomaterial complexes and network assemblages refer to the degree of compatibility with the broader system—with financiers, electricity providers, automobile companies, transport planners, and drivers. Where the network extends, EVs become possible and even desirable; where it is

contested and may face regimes dependent on fossil fuels and conventional cars, EVs are less likely and more controversial.

The presence of commensurability also implies that its inverse can occur—incommensurability will result when adoption fails or incumbent actors reject or resist other forms of mobility. It lastly supposes that such complexes must remain commensurate with expectations and lifestyle choices. The automotive manufacturer Chevrolet ironically made this point in their advertisements for the all-electric Volt by noting that it "came out of the closet" to represent a different lifestyle than its "parents" in Figure 3.

Figure 3: Advertising Campaign for the Chevrolet Volt at the Detroit Motor Show, 2012



Source: Modified from Schwanen (interview with author, 2016).

Sometimes such commensurability is framed as a hybridization of hybrids. Not only the hybrid "electric battery" and "gas generator" depicted in Chevrolet's advertisement above, but a

broader hybridity with particular infrastructural and sociomaterial structures. David A. Kirsch (interview with author, 2016) explains it this way:

> *Successful diffusion of new automotive technology—whether a way of manufacturing, or the adoption of a new device such as an electric vehicle—requires a hybridization of different elements of a sociotechnical system. These cut across system, artifact, organization, and business levels. At the system level, one must integrate original equipment manufacturers and their associated contractors. At the artifact level, one must stitch together internal combustion engines, frames, wheels, and other bric-a-brac. In fact, the internal combustion car is already a hybrid in a sense, since it is composed of mechanical, electrical, and other systems. At the organizational level, one has an alignment of institutions that bridge political divisions and address institutional problems. The term "system builder" or "intermediary" is often used to describe actors that perform these roles of problem solving. The business model level reflects what owners will want to do with their cars when driving and when not in use. The system, in a way, is a hybridization of already created hybrids.*

The topic of commensurability, again, has been confirmed in the peer-reviewed literature. Many studies mention the necessity of easily accessible and/or cheap or free charging infrastructure along with competitive (or free) electricity tariffs and improvements in battery range as vital to the adoption of EVs (Blank and Jones 2015; Habib et al. 2015; Adler et al. 2016; Dong et al. 2015). The specific notion of "range anxiety" has emerged to reflect the problem of EV drivers developing negative psychological feelings of anxiousness when they consider whether they will be able to properly recharge their vehicle on a longer trip (Pasogluu et al. 2015; Franke and Krems 2013a; Frank and Krems 2013b; Franke et al. 2012; Neubauer et al. 2014). Indeed, some research has indicated that the notion of battery range and range anxiety is the single most important factor in whether a user will consider driving or purchasing an EV (Egbue and Long 2012; Duigou et al. 2014).

Other studies have focused on the second half of the equation: contingency and the context dependent nature of transitions to EV adoption. Cowan and Hulten (1996) trace the formative years of the automobile industry when no technology dominated; a rise to dominance; a

consolidation of power; and newer phases of possible disentrancement and decline due to the rise of EVs. Kirsch (2000) suggests that history exerts a "burden" that EVs must overcome, and a degree of contingency in mobility pathways as well: there would have been a time when even dominant regimes today were nascent and emerging. Wells and Cipcigan (2012) talk about the salience of timing and "temporality" in any successful model shift to EVs; Melton et al. (2016) demonstrate the import of "hype cycles" and inconsistent societal attention concerning the legitimacy of alternative transportation pathways.

6.4 Habitual momentum

Habitual momentum reflects experience and habit from the UTAUT, hybridity from Automobility, and actants and lieutenants from ANT. It is through this process that user actions, habits, routines—or circuits of practice—become cemented and crystalized. Habitual momentum implies that as one becomes used to driving an EV—or other forms of mobility—they form attachments and make the behavior seem rational. As Nye (1999: p. 180) has written:

> *The energy systems a society adopts create the structures that underlie personal expectations and assumptions about what is normal and possible … Each person lives within an envelope of such natural assumptions about how fast and far one can go in a day, about how much work one can do, about what tools are available, about how that work fits into the community, and so forth. These assumptions together form the habitual perception of a sustaining environment that is taken for granted as always there*.

Such socio-technological or socio-cognitive environments appear natural because they have been there since the beginning of an individual's historical consciousness. An infant, Nye comments, born into a world with fast-moving automobiles learns to see the world naturally at hundreds of kilometers an hour. Tim Schwanen (interview with author, 2016) confirmed this point when he says that:

> *The process of habituation is important to remember. People become accustomed to difficult things, they forget they had to be learned. Drivers often forget the effort*

> *required—and now normalized—into learning how to drive a car, or into fueling vehicles at a petrol station.*

Psychologists often discuss this "naturalization" process using the term "habituation," in which repeated applications of a stimulus (such as moving quickly) results in decreased responses and eventual immunity to it (Hirsh et al. 2013). Lewin's (1947) foundational three-stage model of change (unfreeze, change, and refreeze) is particularly insightful here, as it suggests that the first stage of "unfreezing" requires individuals to overcome the behavioral inertia of their current habits.

In much the same way, drivers of EVs can become quickly accustomed to electric mobility and perceive its strengths (as relatively effortless, cleaner and quieter transportation) rather than dwell on its weaknesses (pollution from excess electricity generation, environmental burdens from manufacturing and disposal of batteries). To use parlance from ANT, the EV performs as an actant that facilitates a unique type of mobility, fusing human and nonhuman elements such as electrical motors and the actual electrons circulating through them together (Callon 1985).

This hybridity between driver and machine becomes taken for granted and "locked in" (Cowan and Hulten 1996), leading to "obduracy" (Dijk 2011). John Urry (interview with author, 2016) reminds us that such path dependence is often unintended and can begin from practices at the micro scale:

> *Automobility reminds us that small causes can have long-term path dependent effects. Many features of conventional motorized transport emerged by accident, they are examples of small transformations ending up exerting large systemic effects.*

Some researchers even refer to this as a sort of learning by driving process of experiential acceptance where one of the greatest predictors towards driving an EV is actual on-the-road, visceral experience with it (Jensen et al. 2013; Ryghaug and Toftaker 2014). Over time, the practice of driving an EV solidifies into a stronger affinity and identity as a particular type of user

and also reflects a higher degree of competence and consciousness. Knowledge about EVs, in other words, is strongly gleaned through using them (Hagman 2003), and this use creates its own momentum towards further reinforcing behavior.

7. The Virtues of Theoretical Synergism

Interestingly, and most relevant for this study, selectively drawing from each of the three theories fills gaps that occur when those theories are utilized by themselves.

For example, Automoblity has been criticized for treating all geographic spaces as homogenous—"something to be journeyed through"—meaning it may miss underlying power structures of elitism as well as friction that occurs when different actors attempt to become mobile (Costas 2013). Böhm et al. (2006) argue that the approach in itself is a contradiction given that it requires a constantly moving target (pun intended). As they write:

> *Automobility is ultimately impossible* in its own terms (emphasis in original). *Its impossibility is contained in the very combination of autonomy and mobility. At the point at which a subject attempts to move, the specifics of that movement – the technologies deployed, the spaces which need to be made available, the consequences of the form and place of movement, and so on – require a set of external interventions to render it possible.*

In addition, the "mobility" school has to some extent been critiqued for not more concretely engaging with agency in change processes (Seiler 2010).

Here, the notions of performance expectancy, effort expectancy, and social influence from the UTAUT dovetail nicely with Automobility's de-emphasis on agency, change processes, and practices—these attributes of the UTAUT are all about decision-making criteria and build on earlier work in behavioral science showing that human agency and especially the notion of experience and habit can exert strong influences over transit choices. As Allison Hui (interview with author, 2016) elaborates:

> *Mobility can be understood as a socially-situated processes of travel or movement that has multiple, crucial relationships to practice. Moreover, focusing upon practices rather than*

> *people as units of study raises questions about how to deal with the variously interconnected mobilities of not only people but also of elements and the mobilities within practice-specific institutions.*

The factors of translation and enrollment from ANT also reveal varying degrees of friction and hegemony and help counter Automobility's exclusive focus with things perpetually mobile.

Moreover, the integrative framework helps ground ANT. Perhaps the most significant critique of ANT is that it is too abstract, since it is skeptical about the existence of any stable social structure, and instead sees a constantly open-ended interaction between multitudes of human and even nonhuman actors (Mackenzie 1999). ANT asks us not to think of society as some kind of external structure shaping technology, and it implies that characterizing "technology" and "society" as two separate things is fundamentally misleading (Bijker and Law 1992). Another admitted shortcoming is that ANT never explicitly defines what an actor is, which remains "an anonymous, ill-defined and indiscernible entity" (Callon 1999). Within ANT scholarship, a person, a plant, a machine, a weather system or even a germ (or an electron) are all referred to as "actors." As Whittle and Spicer (2004) note:

> *What may be simply a 'rock' for the accident-prone stumbler could become re-imagined as a sedimentary layer for a geologist, a precious stone for a jewel miner or an ornamental pebble for a landscape gardener, each with their own definitions of what a rock 'is' and 'does'.*

Most seriously, by looking closely at the organizational outcomes from technical systems, ANT is less useful at understanding how or why similar technologies can be interpreted or used in different ways (Bijker and Law 1992). ANT lastly sometimes fails to take an evaluative stance on technology, with most analyses confining themselves to the analytical or descriptive realm, rather than the prescriptive realm (Grin et al. 2010).

The UTAUT and Automobility help concretize and focus ANT so it does not get lost in the vastness of a perceived network, especially highlighting elements that contend with decision-making processes of human adopters and users. As Peter Wells (interview with author, 2016) states:

> *I take the view that technologies, albeit those developed in a specific context for specific purposes, are not entirely reducible to that, which is to mean that cars or electric vehicles are both conservative and radical depending on the user. Some (people, organizations) have the primary aim of making the electric vehicle just like an ordinary car: buy them, use them, then make some more, and so on, these types of approaches are focused on adapting electric vehicles to the conventional car agenda. Others, however, are promoting EVs as a way of offering a new performance and economic package and with that offer one can imagine a redesign of business models, the relationship with the consumer, and even mobility. There are many possibilities around the necessity to change use patterns and the different economic opportunities this opens up.*

To accommodate this heterogeneity, the UTAUT's hedonic motivation and Automobility's identity and symbolism exhibit how a single artifact can indeed come to be perceived or valued for very different (and at times contradictory) reasons. Vagueness in the unit of analysis is countered in part by the concreteness of the UTAUT. Additionally, the call from Automoibility to look at system wide effects (positive and negative) also helps counter the lack of normativity within ANT.

The UTAUT, finally, has had so far only limited application to the domain of energy systems or automobiles, with only one study (to the author's knowledge) directly applying it to electronic bicycles (e-bikes) in China (Wolf and Seebauer 2014). In addition, the UTAUT relies on a relatively narrow conception of the user—in this instance office worker, and later, purchaser or adopter of technology. The UTAUT does not readily specify the relative weight and significance of its various constituent elements nor does it capture qualitative aspects of acceptance difficult to measure outside of formal organizations, such as interpersonal social networks or informal

learning (Straub 2009; Im et al. 2011). Moreover, the UTAUT focuses on the adoption of the new, but not the retention of the old—creating somewhat of a deep-seated bias and preference for newness and positive stories of change. Nonetheless, the obduracy of the old may be a critical contingent factor in shaping the adoption of new technologies and practices (Edgerton 2007).

The elements of complexes, identity, pleasure and hybridity from Automoiblity help contrast these shortcomings in the UTAUT by focusing intently on motorized transport, and ANT rectifies the lack of focus or treatment of agents as homogenous. Both Automobility and ANT also highlight the contingency, incumbency, and obduracy of sociomateiral systems, emphasizing power relations and historical inertia that the UTAUT may miss. As John Urry (interview with author, 2016) explains:

> *Automobility is a meta-theory, it assesses the incredible enduring power of a system that is not just cars and roads but oil supplies, geopolitics and relationship between countries, the whole configuration. Automobility looks at the way those elements are interlocked, the power of the system, including its major companies and its resulting conflicts organized around oil.*

Frank Geels (interview with author, 2016) adds that:

> *The system of Automobility fuses together different scales and types of activities. It involves the manufacturing and sale of cars, electric and conventional. It involves household mobility practices such as commuting to work, driving to shopping malls or dropping children off at school. It also involves financing and investment trends, including the valuation of resources and assets.*

And Tim Schwanen (interview with author, 2016) indicates that Automobility helps reveal that:

> *Infrastructure is a relational achievement, a process. It involves dynamic constellations emerging from an interplay of artifacts, computer codes, practices, maintenance, knowledge, and embedded values. Infrastructure also results in different effects. Some of them are technical, such as moving people and stuff around. Some are representational, connected to symbolic impressions of ideas. And some are affective and emotive, and connected to feelings of ambient experience, discomfort, and belonging.*

In sum, each theory has merit, but by focusing only on a single dimension ("mobility," "networks," or "adoption") each misses what the others offer. Perhaps counter intuitively, each of the above theories has elements that are "right"—and thus, taken in isolation, they are partially "wrong". As Tim Schwanen (interview with author, 2016) argues:

> *There is very little work looking at the interplay of production, regulation, consumption, and usage, nothing that unifies or integrates it all. So a master theory may be useful, one that can understand or reveal the dynamic interplay and action-reaction cycles people and technology go through.*

Similarly, Peter Wells (interview with author, 2016) comments that:

> *A majority of transportation is waste, it's something we are compelled to do rather than something we would chose to do. One can debate whether that changes over time given infrastructure and other issues that arise from social practices or embedded sociotechnical systems, but in that sense my perception is that mobility is not driven by any single economic or psychological theory, though I can see lots of compulsion behind why people travel. It's a problem not reducible to one perspective or another, that's the nature of mobility and transport generally. It is locked into wider social structures and frameworks arising out of other features and pressures which shape mobility around it. Therefore, one needs an array of theories and concepts.*

The implication is that single theories each miss insight from the others—the UTAUT theorists may miss the importance of mobility and hybridity that can occur between drivers and cars; the Automobility theorists may miss the ways that performance and ease of use can influence preferences; the ANT theorists can fail to incorporate elements of interpretive flexibility that can occur with perceptions and intentions concerning the same "artifact," e.g., an EV.

Despite the virtues of synergism, however, no single framework, no matter how integrative, will adequately explain all possible patterns of EV adoption and non-adoption, nor will it be persuasive to all universal audiences. There are, nonetheless, salient parts of each theory that can be utilized fruitfully together. In line with Watson (2012), I maintain that the integration of theories across the domains of mobility, technology, and user practice make possible new fields of

investigation of their own and also create new analytical tools that could have more explanatory power, rigor, and coherence than those that currently exist in the transport studies community.

8. Conclusion

The integrative framework of electric mobility I present—consisting of motile pleasure, sociality, sociomaterial commensurability, and habitual momentum—attempts to draw from three previously isolated schools of thought concerning mass mobility (Automobility), science and technology (Actor Network Theory), and management science and the acceptance of information systems (the UTAUT). As Table 5 summarizes, each of its four components synthesize from the fifteen previously disparate constructs elaborated upon in Automobility, ANT, and the UTAUT. As the integrated framework proposes, *motile pleasure* suggests that drivers will value not only the purchase price, performance, or ease of use of an EV when deciding their intentions but also other nontechnical factors underlying or contributing to a sense of individual satisfaction or rectifying a social need. *Sociality* affirms the strong influence that norms and interpersonal networks (or lack thereof) can play in motivating and then enrolling and socializing adopters and non-adopters. *Sociotechnical commensurability* implies that compatible charging, fueling, and maintenance infrastructure must exist so that EVs are seen to be as reliable as the network assemblage undergirding their conventional counterparts. *Habitual momentum* implies that a process of "learning by driving" can acclimate and even socialize adopters into a new affinity group of EV drivers that can "freeze" into new behavioral patterns.

Table 5: Theoretical Components of an Integrated Framework for Electric Mobility

Component	Synthesized from the UTAUT	Synthesized from Automobility	Synthesized from ANT	Application to electric mobility
Motile pleasure	Performance expectancy, effort expectancy,	Driving pleasure	Translation (problematization)	Drivers will value purchase price, performance, and ease of use but also other considerations such as safety,

	hedonic motivation			insulation from rising petroleum prices, or energy security
Sociality	Social influence	Social identification and symbolism	Enrollment (interesessment, enrollment, mobilization)	Drivers will be influenced by subjective norms along with affective/emotional responses related to interpersonal networks (the influence of other actors) and image
Sociotmaterial commensurability	Facilitating conditions, price value	Sociomaterial systems	Network assemblage	Drivers will require commensurate infrastructure such as charging stations and available electricity to minimize range anxiety
Habitual momentum	Experience and habit	Hybridity	Actants and lieutenants	Drivers will come to solidify their positive (or negative) experiences with EVs over time through a process of naturalization or habituation

Source: Author. Note: UTAUT = The Unified Theory of Acceptance and Use of Technology. ANT = Actor Network Theory.

In strategically and selectively borrowing from these three disparate theories, my hope is that the proposed framework is able to avoid gaps and capture strengths. The UTAUT has only rarely expanded beyond office technologies or simple household technologies, whereas the framework above enables their application to transport modalities and motile pleasure. The integrative framework provides a more holistic conception of the user, moving beyond merely a driver or purchaser to other types such as salespersons or mechanics. The UTAUT has been criticized for downplaying underlying power structures, but this is offset by sociomaterial commensurability. Automobility has been critiqued for focusing less on agency and decision-making processes, but this is ameliorated by motile pleasure and habitual momentum which unpack how choices get made and the types of historical inertia that can result. The processes of recruitment, enrollment, and translation reveal how norms and habits to driving spread. ANT has been seen as fairly vague and treating technologies as one-dimensional, but this is mitigated by sociality's notion that a single artifact can evoke competing and contradictory perspectives. The framework here also helps ground ANT concepts—in this particular case, actors are users of EVs

and the network is defined by by Automobility and a particular sociomaterial regime of mass mechanized transport (currently undergirded by fossil fuel extraction and internal combustion engines). My hope is that the framework here is more than just a mishmash or compendium of models, or a subsequent minor tinkering of the UTAUT—its whole is greater than the sum of its parts.

That said, further research would confirm (or perhaps disprove) this point. The validity of the proposed framework needs examined, and future research could assess the proposed structure using factor analysis and then utilize regression to validate the predictive power of the framework, as many studies utilizing the UTAUT have done, or rely on agent based modeling to try and capture the influence of actants, even human ones. Whether the elements of these theories really can be integrated, especially Actor Network Theory's rejection of a priori network construction with UTAUT's preference for factor analysis and quantification, is still subject to debate. Moreover, the predictive "fit" or usefulness of the concepts of motile pleasure, sociality, sociomaterial commensurability, and habitual momentum could be qualitatively evaluated based on field work and actual user feedback. Do the conceptual components work in the face of insights from EV users and empirical case studies, for example?

Although the core of this article is theoretical, some policy implications arise as well. The mix of original interview data and peer-reviewed literature parsed for this study suggest that personal choices about private transportation create a culture of mobility, with momentum and inertia, which can subordinate other types of transport (such as walking, cycling, or mass transit) and contribute to a personal sense of identity. For shifts to other modes to occur, they must find a way to substitute for the services and cultural comforts of the traditional systems or artifacts it will be replacing. In short: automobiles are not just about multiple dimensions or scales, as some

theories suggest, but multiple services differentiating personal identity and driving practices. User attitudes, values, and visions become just as important as improved tires, better fuel economy, longer lasting batteries, and tougher and lighter materials in why people embrace particular forms of mobility. We ought to recalibrate not only our theoretical frameworks, but our research efforts and expectations accordingly.

9. Appendices

Appendix I: Research Interview respondents (n=35)

No.	Date	Name	Discipline	Institution	Country

1	October, 2015	Thomas Dietz	Environmental sociology	Michigan State University	United States
2	October, 2015	Paul C. Stern	Behavioral science	National Research Council	United States
3	December 2015	Ihonen Jari	Engineering	VTT (Technical Research Centre of Finland)	Finland
4	January 2016	John Urry	Sociology	Lancaster University	United Kingdom
5	January 2016	Johan Schot	History	University of Sussex	United Kingdom
6	January 2016	Frank Geels	Innovation studies	Manchester University	United Kingdom
7	January 2016	Rene Kemp	Sustainable development, innovation and social transitions	Maastricht University	Netherlands
8	January 2016	Harro Van Lente	Science and technology studies	Maastricht University	Netherlands
9	January 2016	Marianne Ryghaug	Interdisciplinary studies of culture	Norwegian University of Science and Technology	Norway
10	January 2016	Peter Wells	Business and sustainability	Cardiff Business School	United Kingdom
11	January 2016	Wiebe Bijker	Science and technology studies	Maastricht University	Netherlands
12	January 2016	Richard Hirsh	History	Virginia Polytechnic Institute & State University	United States
13	February 2016	Gordon Walker	Sociology	Lancaster University	United Kingdom
14	February 2016	Giulio Mattioli	Transport Studies	University of Leeds	United Kingdom
15	February 2016	Sheila Jasanoff	Science and technology studies	Harvard University	United States
16	February 2016	Mimi Sheller	Sociology, anthropology	Drexel University	United States
17	February 2016	David Nye	History	University of Southern Denmark	Denmark
18	February 2016	Trevor Pinch	Science and technology studies	Cornell University	United States
19	February 2016	Marilyn Brown	Public policy	Georgia Institute of Technology	United States

20	February 2016	Frank Southworth	Engineering	Georgia Institute of Technology	United States
21	February 2016	David A. Kirsch	Business history	University of Maryland	United States
22	February 2016	Jillian Anable	Transport studies	University of Aberdeen	United Kingdom
23	February 2016	Willett Kempton	Energy policy	University of Delaware	United States
24	February 2016	Linda Steg	Behavioral science	University of Groningen	Netherlands
25	February 2016	Jonn Axsen	Transport studies	Simon Fraser University	Canada
26	February 2016	Tim Schwanen	Transport studies	University of Oxford	United Kingdom
27	February 2016	Donald Mackenzie	Science and technology studies	University of Edinburgh	United Kingdom
28	February 2016	Edward Hackett	Human evolution and social change	Arizona State University	United States
29	February 2016	Marc Dijk	Transport studies	Maastricht University	Netherlands
30	February 2016	Matthew Watson	Sociology, human geography, sustainability	University of Sheffield	United Kingdom
31	February 2016	Adrian Smith	Science and technology policy, grassroots innovation	University of Sussex	United Kingdom
32	March 2016	Allison Hui	Sociology	Lancaster University	United Kingdom
33	March 2016	Sharlissa Moore	Science and technology studies	Michigan State University	United States
34	March 2016	Robert O. Keohane	Political science	Princeton University	United States
35	April 2016	Andy Stirling	Science and technology studies	University of Sussex	United Kingdom

Appendix II: Theories, Concepts and Frameworks Mentioned by Respondents (n=54)

No.	Discipline	Name
1	Behavioral science	Attitude-Behavior-Context (ABC) Theory
2	Behavioral science	Comprehensive Technology Acceptance Framework
3	Behavioral science	Consumer Preference Theory
4	Behavioral science	Expectancy-Value Theory

5	Behavioral science	Four Dimensions of Behavior (4DB) Framework
6	Behavioral science	Integrated Framework for Encouraging Pro-environmental Behavior (IFEP)
7	Behavioral science	Interpersonal Behavior (TIB)
8	Behavioral science	Lifestyle Theory
9	Behavioral science	Motivation-Ability-Opportunity Model
10	Behavioral science	Norm Activation Theory/Model
11	Behavioral science	Protection Motivation Theory
12	Behavioral science	Subjective Expected Utility (SEU)
13	Behavioral science	Symbolic Interactionism
14	Behavioral science	Symbolic Self-Completion Theory
15	Behavioral science	Theory of Planned Behaviour (TPA)
16	Behavioral science	Theory of Reasoned Action (TRA)
17	Behavioral science	Transtheoretical Model
18	Behavioral science	Values-Beliefs-Norms Theory
19	Consumption studies	Domestication Theory
20	Development studies	Sustainable Development
21	Economics	Rational Choice Theory
22	Energy studies	Energy Cultures Framework
23	Information science and management studies	Initial Trust Model
24	Information science and management studies	Motivational Model
25	Information science and management studies	Social Cognitive Theory
26	Information science and management studies	Task Technology Fit Model
27	Information science and management studies	Technology Acceptance Model (TAM)
28	Information science and management studies	Unified Theory of Acceptance and Use of Technology (UTAUT)
29	Innovation studies	Design Driven Innovation
30	Innovation studies	Diffusion of Innovations Theory
31	Innovation studies	Multilevel Perspective (MLP) on Innovation
32	Innovation studies	National Innovation Systems (NIS)
33	Innovation studies	Regime Evolution Framework
34	Innovation studies	Regional Innovation Systems (RIS)
35	Innovation studies	Technological Innovation Systems (TIS)
36	Innovation studies	Triple Embeddedness Framework and the Dialectical Issue Life Cycle Model
37	Legal studies and jurisprudence	Social Justice Theory
38	Linguistics and semiotics	Discourse Theory
39	Marketing	Theory of Buyer Behavior
40	Mathematics	Systems Theory
41	Organization studies	Complexity Theory

42	Organization studies	Sociomateriality
43	Organization studies	Theory of Institutional Entrepreneurship
44	Science and technology studies	Actor Network Theory
45	Science and technology studies	Coproduction
46	Science and technology studies	Large Technical Systems
47	Science and technology studies	Social Construction of Technology (SCOT)
48	Science and technology studies	Sociology of Expectation
49	Science and technology studies	Sociotechnical Imaginaries
50	Sociology	Automobility
51	Sociology	Social Action Theory
52	Sociology	Social Practice Theory/Theories of Practice
53	Transport studies	Perspectives of Interpersonal Influence
54	Transport studies	Reflexive Layers of Influence

Source: Author's compilation of research interviews and materials suggested by participants.

Appendix III: Models Incorporated into the Unified Theory of Acceptance and Use of Technology (UTAUT)

Model/theory	**Description**	**Core constructs**	**Selected key work(s)**
	Drawn from social psychology, TRA has	Attitude Toward Behavior: an individual's positive or	Azjen 2002; Davis 1989; Davis et al.

Theory of Reasoned Action	been utilized to predict a range of behaviors.	negative feelings (evaluative affect) about performing the target behavior	1989; Sheppard et al. 1988; Fishbein and Azjen 1975
		Subjective Norm: the person's perception that most people who are important to them think they should or should not perform the behavior in question	
Technology Acceptance Model	Tailored to information system contexts, TAM was intended to predict technology acceptance and usage on the job; unlike TRA it excludes the attitude construct.	Perceived Usefulness: the degree to which a person believes that using a particular system would enhance his or her job performance	Venkatesh and Davis 2000; Davis 1989
		Perceived Ease of Use: the degree to which a person believes that using a particular system would be free of effort	
		Subjective Norm: the person's perception that most people who are important to them think they should or should not perform the behavior in question	
Motivational Model	Applied motivational theory to explain behavior	Extrinsic Motivation: The perception that users will want to perform an activity because it is perceived to be instrumental in achieving valued outcomes that are distinct from the activity itself, such as improved job performance, pay, or promotions	Venkatesh and Speir 1999; Vallerand 1997; Davis et al. 1992.
		Intrinsic Motivation: The perception that users will want to perform an activity for no apparent reinforcement other than the process of performing the activity per se	
	Extended TRA by adding the notion of	Attitude Toward Behavior: an individual's positive or	Azjen and Fishbein 2000; Taylor and

Theory of Planned Behavior	Perceived Behavioral Control	negative feelings (evaluative affect) about performing the target behavior	Todd 1995; Azjen 1991
		Subjective Norm: the person's perception that most people who are important to them think they should or should not perform the behavior in question	
		Perceived Behavioral Control: the perceived ease or difficulty of performing the behavior	
Combined TAM and TPB	Unified the predictors of TDP with the perceived usefulness from TAM to create a hybrid model	Attitude Toward Behavior: an individual's positive or negative feelings (evaluative affect) about performing the target behavior	Taylor and Todd 1995
		Subjective Norm: the person's perception that most people who are important to them think they should or should not perform the behavior in question	
		Perceived Behavioral Control: the perceived ease or difficulty of performing the behavior	
		Perceived Usefulness: the degree to which a person believes that using a particular system would enhance his or her job performance	
Theory of Human Behavior	Designed to predict individual acceptance of new technologies or practices at the workplace	Job-fit: the extent to which an individual believes that using a technology can enhance job performance	Thompson et al. 1991; Triandis 1977; Rogers and Shoemacher 1971
		Complexity: the degree to which an innovation is perceived as relatively difficult to understand and use	
		Long-Term Consequences: Outcomes that have a payoff in the future	

		Affect Towards Use: feelings of joy, elation, or pleasure, or depression, disgust, displeasure, or hate associated by an individual with a particular act	
		Social Factors: the individual's internalization of the reference group's subjective culture, and specific interpersonal agreements that the individual has made with others, in specific social situations	
		Facilitating Conditions: Objective factors in the environment that observers agree make an act easy to accomplish	
Innovation Diffusion Theory	Intended to present a sociological theory of how various innovations diffuse into the market place	Relative Advantage: the degree to which an innovation is perceived as being better than its precursor	Moore and Benbasat1991; Rogers 1995; Agrawal and Prasad 1997; Karahanna et al. 1999; Plouffe et al. 2001
		Ease of Use: the degree to which an innovation is perceived as being difficult to use	
		Image: The degree to which use of an innovation is perceived to enhance one's image or status in one's social system	
		Visibility: The degree to which one can see others using the system in the organization	
		Compatibility: the degree to which an innovation is perceived as being consistent with the existing values, needs, and past experiences of potential adopters	
		Results Demonstrability: the tangibility of the results of	

		using the innovation, including their observability and communicability	
		Voluntariness of Use: the degree to which use of the innovation is perceived as being voluntary, or of free will	
Social Cognitive Theory	Proposed that knowledge acquisition could be connected to observing others within the context of social interactions, experiences, and outside media influences	Outcome Expectations Performance: The job performance-related consequences of the behavior	Compeau et al. 1999; Compeau and Higgens 1995; Bandura 1986
		Outcome Expectations Personal: The personal consequences of the behavior such as individual esteem and sense of accomplishment	
		Self-Efficacy: Judgment of one's ability to use a technology (e.g., a car) to accomplish a particular job or task	
		Affect: An individual's liking for a particular behavior (e.g., driving)	
		Anxiety: Evoking anxious or emotional reactions when it comes to performing a behavior	

Source: Modified from Venkatesh et al. 2003.

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